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Abert Squirrel Cover Requirements in Southwestern Ponderosa Pine

David R. Patton

Abstract

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Describes the characteristics of ponderosa pine trees and stands selected by the Abert squirrel for cover. Presents data on basal area, tree density and size, tree vigor, dominance and age class, nest location and nest tree density in a pine forest. Discusses the data's relevance for evaluating the quality of Abert squirrel habitat.

Keywords: Abert squirrel, ponderosa pine, habitat evaluation, squirrel cover.

PREFACE

Criteria for optimum squirrel cover presented in this study were from data obtained in an area where man had not overcut the forest. The trend for forest management in ponderosa pine is going toward large single-aged stands, with trees spaced more evenly. In such a stand the effect of tree grouping and great diversity could be destroyed, and I suspect Abert squirrel habitat also.

Keith (1965) pointed out the dependence of Abert squirrels on ponderosa pine, McKee (1941) alluded to the evolutionary aspects of pine and squirrels, and implicit in this study is the close association of tree size, density, and grouping to provide squirrel nest cover. These factors cannot be denied if the Abert squirrel is to remain part of the ponderosa pine ecosystem. There will need to be trade-offs between wood production and squirrel habitat. Biologists and foresters must work together to insure that future timber stands and squirrel habitat start with ponderosa pine seedlings.

Special recognition is due Dr. D.I. Rasmussen, U.S Forest Service (retired). His observations and many years of field experience provided a background from which I could draw to develop research concepts.

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INTRODUCTION

Ponderosa pine[2] is the most widely distributed pine in North America; it ranks second in timber production in the western United States. Commercial ponderosa pine in the Southwest occupies about 11 million acres mostly in Arizona, Colorado, and New Mexico (fig. 1). Of the many wildlife species inhabiting the ponderosa pine forest, none are more dependent on pine for food and cover than the Abert squirrel. The relationship is even more interesting because the distribution of Abert subspecies coincides with disjunct ponderosa pine forests. Since pine is an important timber species, increasing national demand for wood products will increase timber harvesting in the southwestern ponderosa pine type, which will directly affect squirrel habitat. Abert squirrel management depends on a knowledge of squirrel food and cover requirements, and how these requirements are changed by changes in the physical and spatial characteristics of the pine forest.

Food habits of this handsome squirrel generally have been determined, and studies still in progress will add to our knowledge, but factual information about cover is lacking. Cover, defined as vegetative shelter, includes the nest, nest tree, and vegetation surrounding the nest tree of an Abert squirrel. The vegetation characteristics preferred for cover need to be identified and quantified so guidelines can be developed to evaluate the quality of squirrel habitat and how quality is affected by forest succession and forest management practices.

The objectives of this study were to determine: (1) density of squirrel nests in a ponderosa pine forest stratified by physical characteristics, (2) physical characteristics of trees selected for nests, and (3) the physical and spatial characteristics of trees surrounding the nest tree. Data collected to satisfy these objectives would be the basis for developing a technique to evaluate Abert squirrel habitat. With this technique the forest wildlife manager could evaluate land management practices that alter the squirrel's environment, and recommend changes in cutting practices to insure that some areas will remain good squirrel habitat.

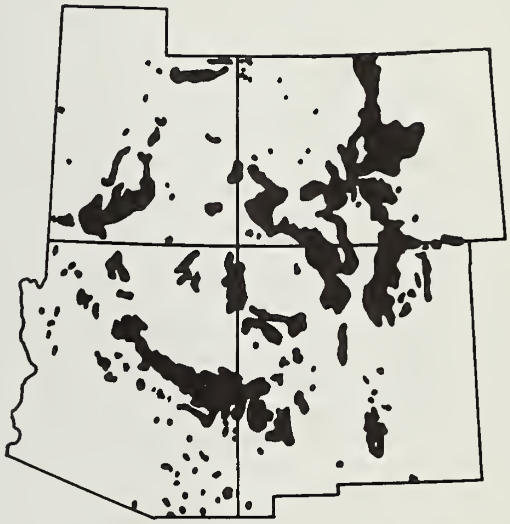

Figure 1.—Occurrence of ponderosa pine in the Southwest.

The Abert Squirrel

The Abert squirrel type specimen was collected from the San Francisco Mountains in Arizona in October 1851 by S.W. Woodhouse. It was named in honor of Lt. James W. Abert, who made natural history observations while on a military expedition to the Southwest (Merriam 1890). Collectively the Abert squirrel sub-

[2]*Scientific names of plants and animals mentioned are listed inside the back cover.*

species (including *Sciurus kaibabensis*) have been described in a subgenus (*Otosciurus*) as tassel-eared squirrels. Opinions differ on whether the Kaibab squirrel is a separate species or a subspecies of the Abert. Merriam (1904) gave the Kaibab squirrel species status, but Cockrum (1960) considers it a subspecies of Abert. The difference in the two squirrels is based on color variation; both appear to have similar habitat requirements.

Abert squirrels are found only in the interior ponderosa pine forests where temperatures are cool and rainfall is moderate (McKee 1941). The interior pine type has been described by the Society of American Foresters (1954) as a separate forest type—Type 237. It differs from other ponderosa pine, particularly in coastal areas, in that it occurs mostly in pure or nearly pure stands at middle elevations where rainfall is less than 25 inches. In Arizona and New Mexico, Gambel oak is a common associate of ponderosa pine. The type occurs just above the pinyon-juniper and below the Douglas-fir zone.

This pine distribution restricts the Abert to Arizona, Colorado, New Mexico, Utah, and parts of Mexico. McKee (1941) believes the present squirrel distribution came about as a result of ponderosa pine disappearing from low elevations because of changes in climate. The Abert did not adapt to other vegetation types, and over thousands of years moved upward with the receding pine forests. Keith (1965) suggests that squirrel populations fluctuate over short periods and that there has been a general downward trend in squirrel numbers. He relates the changes to logging and a failure of ponderosa pine to regenerate.

Keith (1965) published the first factual information on the food and cover requirements of the Abert squirrel. His paper provided evidence the Abert depends solely on ponderosa pine for most of its life necessities. In 1964 I began a study on the Apache National Forest to learn more about the Abert squirrel and its habitat (Patton and Green 1970). The objective of that earlier study was to determine sizes of ponderosa pine selected by squirrels for feed trees to provide data to forest managers to coordinate squirrel management with timber harvesting.

The Abert Squirrel's Habitat

Research indicates trees between 11 and 30 inches diameter at breast height (d.b.h.) are preferred for feed trees (Patton and Green 1970). The frequency distribution of tree diameters used by squirrels on the Kaibab National Forest[3] is close to that reported on the Apache National Forest (Patton and Green 1970).

Feed tree density varies considerably and probably reflects different squirrel numbers and different measurement techniques. Squirrels used from 0.6 to 4.7 trees per acre on the Manti-LaSal National Forest in Utah depending on whether the stand was cut or uncut.[4] On the Kaibab National Forest, Hall[5] found number of trees used per acre varied by year from 0.5 to 6.0. Computations from Arizona Game and Fish Department surveys, however, showed 2.4, 14.1, and 11.7 feed trees per acre for 1968, 1969, and 1970, respectively.[3]

Although there is some indication that squirrels prefer certain trees for feeding[5] (Goldman 1928, Keith 1965, Pearson 1950), the criteria for choice of feed trees has not been determined. A qualitative difference in trees has been suggested by Keith (1965), but Hall[5] could not validate this difference in his chemical analyses.

Cover preference of Abert squirrels has not been established except for casual observations and some limited data. Several people[5] (Bailey 1931, Cahalane 1947, Goldman 1928, Patton and Green 1970, Warren 1910) indicate that squirrels most frequently nest in ponderosa pine. Other tree species have been used for nests, mainly Gambel oak (Patton and Green 1970). Nest trees in Arizona vary in size from 12 to 41 inches d.b.h. at Fort Valley (Keith 1965), from 10 to 24 inches d.b.h. in Castle Creek (Patton and Green 1970), and from 11 to 28 inches d.b.h. on the Kaibab National Forest.[3]

The habitat surrounding the nest tree is probably more important than the nest tree itself. At Castle Creek, Patton and Green (1970) identified a tree density factor that suggested minimum amounts of cover for maintenance of squirrel habitat. A squirrel nest is generally found in a tree that is one of a group of trees of similar size, but sometimes nests are found in

[3]*Rasmussen, D.I. 1972. National and international interest in the Kaibab squirrel: A problem analysis. 91 p. (Unpublished report prepared by Reg. 3, USDA For. Serv., Albuquerque, N. Mex., on file at Rocky Mt. For. and Range Exp. Stn., Tempe, Ariz.)*

[4]*Butler, J.J., and G. Richardson. 1969. Abert squirrel activity in the Arch Canyon and Babylon timber sales, Monticello Ranger District, Manti-LaSal National Forest, Price, Utah. 5 p. (Unpublished report on file at Rocky Mt. For. and Range Exp. Stn., Tempe, Ariz.)*

[5]*Hall, J.G. 1967. The Kaibab squirrel in Grand Canyon National Park: A seven seasons summary 1960-1966. 54 p. (Unpublished report prepared by Natl. Park Serv., U.S. Dep. Inter., Grand Canyon, Ariz., on file at Rocky Mt. For. and Range Exp. Stn., Tempe, Ariz.)*

isolated trees. All nest trees on the Kaibab National Forest were located in groups of trees that provide access to the nest tree by interlocking or close tree crowns.[3] Such a grouping provides protection from weather plus alternate escape routes.

Ponderosa pine exists mainly as a climax forest in the Southwest (Pearson 1950). Although tree species composition in the pine type is rather simple, the spatial distribution of trees is very complex. Cooper (1961) described four scales of patterns, from a large scale induced by topography to a small scale of individual arrangement of trees in a stand. Characteristically, ponderosa pine in the Southwest grows in irregular uneven-aged stands, with even-aged groups within the stands (Schubert 1973). Groups vary from a few trees of similar size occupying about 1/100 acre to many trees on areas of 1/20 to 1/5 acre. Cooper (1961) suggests reasons for this group pattern: the species is intolerant to shade and natural fires oppose a random vegetation distribution.

Availability of squirrel food items is directly associated with the morphology and phenology of ponderosa pine. Ponderosa has both staminate and pistillate flowers on the same individual (monoecious). Flowering usually begins in May, and pollen is shed in June. After pollination the female flower develops slowly the first summer. Although the female conelet has been pollinated, fertilization is delayed until the following spring. The cone then develops rapidly and reaches maturity in August and September.

Staminate flowers are eaten by the Abert in May and June, and squirrels are often seen with a yellow "pollen" face. Ovulate cones are consumed from May to November when the last seed generally has been shed. Inner bark and apical buds become the squirrel's main food source during winter months, especially when snow covers the forest floor. Acorns and fungi are readily eaten when they are available.

STUDY AREA

Squirrel-pine relationships were studied on watershed 8 of the Beaver Creek Pilot Watershed, 25 miles south of Flagstaff, Arizona, on the Coconino National Forest (fig. 2). This area was selected because it had a good squirrel population, a variety of ponderosa pine stand conditions, and easy access. Also, supporting information in the form of maps, aerial photographs, timber inventory, and a soil survey was available.

Landscape

Watershed 8, an area of 1,765 acres, varies from 6,900 feet elevation at the lower end to 8,020 feet on top of Lake Mountain. It is part of the Grand Canyon section of the Colorado Plateau physiographic province (Fenneman 1931). Slopes are gentle in the center of the watershed, but become steep around Lake Mountain and along the stream drainage below Butch Tank. Drainage is west into the Verde River. The watershed had been logged twice, once in 1930 and again in 1950. The latter was a selection cut which removed approximately half of the commercial volume.

Climate

Climate in watershed 8 is similar to that of Flagstaff. The coldest month is January, with an average minimum of 14° F and an average maximum of 40° F. August is the warmest month; the average minimum temperature is 50° F and the average maximum is 81° F. Two distinct precipitation seasons are evident: summer rains come in July and August in thunderstorms, while winter precipitation is in the form of snow. Average precipitation is 24 inches; about 5 inches of this falls during July and August.

Soils

There are five soil series (Brolliar, Cabezon, Friana, Siesta, and Sponseller) within the watershed boundary (Williams and Anderson 1967). Brolliar, the most important, covers 70 percent of the study area. It consists of moderately deep and deep, well-drained, noncalcareous material on nearly level to hilly uplands, formed from weathered porous basalt. The surface layer of Brolliar is dark brown, soft when dry, and has a blocky structure. Basalt bedrock is at a depth of 2 to 5 feet. Stones and cobbles cover 20 to 60 percent of the surface of most areas. Litter of decomposed and partly decomposed pine needles overlies the mineral soil.

Flora and Fauna

Ponderosa pine is the dominant plant species in the study area. Small clumps and single trees of Gambel oak and New-Mexican locust are scattered throughout the pine. Aspen occurs along cool drainages, but is not a major component of the overstory.

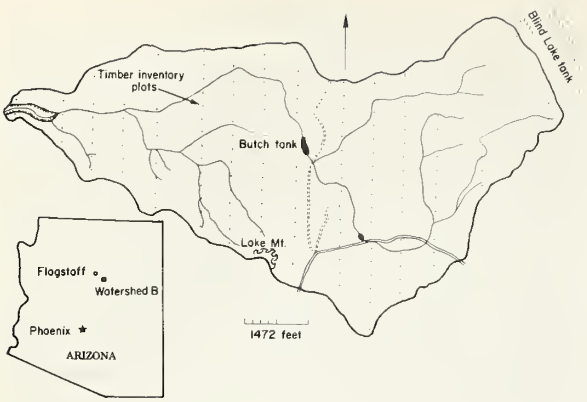

Figure 2.—Location of study area—watershed 8 (1,765 acres) of the Beaver Creek Pilot Watershed, Coconino National Forest, Arizona.

Understory species include Arizona fescue, Junegrass, blue grama, mountain muhly, geraniums, peavine, and clovers. Woody understory species are not abundant, but oak, locust, and Fendler ceanothus are present.

Common mammals found in the watershed are mule deer, elk, cottontail rabbit, bobcat, coyote, raccoon, and red squirrel.

Many species of birds inhabit the study area, but those seen most often are the pygmy nuthatch, violet-green swallow, gray-headed junco, mourning dove, red-tailed hawk, goshawk, and wild turkey.

METHODS

My approach to experimental design was to inventory and describe areas used by squirrels for cover. Each area was located by the presence of a nest.

An existing timber inventory system for watershed 8, consisting of 180 points identified on the ground and on a base map, was used by a field crew to search systematically for squirrel nests. The crew marked each nest tree with a numbered aluminum tag and orange flagging, plotted its location on the base map, and then used it as the center of a 1/10-acre plot to inventory the trees surrounding the nest tree.

Species and diameter, measured at 4.5 feet (d.b.h.), were recorded for all trees on the plot. Diameters were rounded to the nearest inch for computing basal area and average tree diameter for trees over 7.5 inches d.b.h. Basal area is the total cross-sectional area in square feet of trees on a per-acre basis. Average diameter generally is determined from basal area, but in this study I averaged the diameters for all trees on the plot.

Plot slope was recorded to the nearest percent and categorized in one of five classes: 5 or less, 6 to 10, 11 to 15, 16 to 20, or greater than 20. Plot exposure was recorded to the nearest degree and assigned to one of eight classes: N, NE, E, SE, S, SW, W, and NW. Plot slope position was recorded as lower, middle, or upper one-third of the total slope. Canopy coverage at the plot was estimated from four spherical densiometer readings taken at the plot center facing north, east, south, and west.

Other factors recorded at the plot were number of trees with the main trunk forked and the amount of ground cover. Ground cover was estimated on five 8- by 20-inch plots systematically spaced at 3-foot intervals along the north radius of the 1/10-acre plot. Cover to the nearest percent was recorded for rock, litter, grass, forbs, bare soil, and woody plants less than 2 feet high.

Age of each nest tree was determined from an increment core removed at d.b.h. Mistletoe-infected nest trees were rated using Hawksworth's (1961) 6-class system. The tree crown is divided into three vertical sections and assigned a value:

0 - No infection
1 - Light infection
2 - Heavy infection

The value for each section is added to obtain a composite rating for the tree.

Nest location (trunk, fork, or limb), nest distance from the ground, nest exposure from the tree trunk, nest tree height, and number of trees interlocking the crown of the nest tree were recorded at the inventory plot.

Nest trees were described by recording age-vigor, tree position, and tree dominance. Age-vigor was recorded by using criteria for ponderosa pine in the Southwest (Thompson 1940):

Age I—Young blackjack pine, seldom over 12 inches d.b.h. and usually less than 75 years old.
Age II—Blackjack pine seldom over 24 inches d.b.h. and usually less than 150 years old.
Age III—Intermediate or young yellow pine less than 36 inches d.b.h. and between 150 and 225 years old.
Age IV—Yellow pine over 225 years old with bark plates long, wide, and smooth.
Vigor AA—Crown is over 70 percent of the tree height.
Vigor A—Crown is between 55 and 70 percent of the tree height.

Vigor B—Crown is between 35 and 55 percent of the tree height.
Vigor C—Crown is between 20 and 35 percent of the tree height.
Vigor D—Crown is less than 20 percent.

Nest tree position indicates the horizontal location of a tree in a group of trees (Pearson 1950). The classifications used were:

Isolated—Tree is free to grow on all sides and is 30 or more feet from other trees.
Open—Tree is detached from a group of trees, but is closer than 30 feet.
Marginal—Tree is growing on the edge of a group of trees.
Interior—Tree is growing inside a group of trees.

Tree dominance indicates vertical position of the tree crown in a stand (Pearson 1950). For ponderosa pine in the Southwest the criteria are:

Isolated—Trees with crowns that receive full light from above and from all sides through the life of the tree.
Dominant—Trees with crowns extending above the general level of the crown cover and receiving full light from above and partly from the side; larger than average trees in the stand.
Codominant—Trees with crowns forming the general level of the crown cover and receiving full light from above, but comparatively little from the sides, usually with crowns crowded on all sides.
Intermediate—Trees shorter than those in the two preceding classes, but with crowns either below or extending into the crown cover formed by codominant and dominant trees. These trees receive little direct light either from above or from the sides.
Overtopped—Trees with crowns entirely below the general level of the crown cover that receive no direct light either from above or from the sides.

RESULTS AND DISCUSSION

Data analysis consists of two parts. First, nest tree density and ponderosa pine crown density classes are compared. Second, physical characteristics of nest trees and physical and spatial characteristics of trees surrounding the nest tree are described from data collected on the 1/10-acre inventory plots. The terms cover site, nest site, plot, and stand all refer to the 1/10-acre inventory plot.

Density of Squirrel Nests

The pine forest in watershed 8 was stratified into three crown density classes. These classes could be identified under a stereoscope using a crown density scale on color aerial photographs. Five acres was the smallest area included in a class. Tree diameters for the three crown density classes were estimated from a dot grid sample within each class by comparing the tree crown under the dot to a crown diameter scale graduated in thousandths of an inch. The measurement was then converted to tree diameter from a regression of tree crown to tree diameter for ponderosa pine. Within each density class, differences in sizes of stands and clumping of trees could be seen on the photographs, but these areas were not delineated because of their small size. These small areas also were the areas that would be described in the nest tree inventory. Thus, the crown density classes are described at a scale large enough to be interpreted from aerial photographs, using standard photographic techniques and aids:

Low Crown Density (Class I)—This class contains mature yellow pine with somewhat homogeneous spacing of single trees. In some areas trees may be grouped. Small stands of saplings (1 to 5 inches d.b.h.) and poles (5 to 9 inches d.b.h.) sometimes are scattered between large groups of mature trees. Trees are generally above 18 inches d.b.h. Crown density is 35 percent or less.

Moderate Crown Density (Class II)—A class containing mature yellow pine mixed with stands of intermediate pine. An open effect results from space between large stands. Large stands may contain subgroups of trees from 1/10 to 1/4 acre in size. Openings between large groups sometimes have evenly spaced single trees. Average diameter of trees in the stands ranges from 14 to 17 inches d.b.h. Crown density is between 36 and 70 percent.

High Crown Density (Class III)—Intermediate and blackjack pines occur in this class in a mixture of densities and diameters. Many stands have one layer, but two and sometimes three layers are formed by several mature trees (15 to 17 inches) protruding through the canopy. Average d.b.h. of these stands is between 11 and 13 inches. Crown density is over 70 percent.

The nest tree distribution map compiled from field locations was used as an overlay to

compare nest tree density with the crown density map delineated from aerial photographs. The highest density of nest trees is in Class III (table 1). Open stands (Class I) contain the lowest density. Within the watershed there were 414 nest trees representing a crude density of one nest per 4.3 acres. However, some areas totaling 144 acres should be excluded because they are different vegetation types: locust thickets (23 acres), meadows (99 acres), and riparian (22 acres). After deducting these 144 acres, the nest tree density in ponderosa pine becomes one per 3.9 acres. Farentinos (1972) found one nest for each 4.4 acres on an area of 178 acres in Colorado.

Table 1.--Nest tree density by crown density classes for ponderosa pine, watershed 8

Crown density class	Average d.b.h. (inches)	Acres	Nest trees	
			No.[1]	Density
I	18≥	297	33	1 per 9.0 acres
II	14-17	989	219	1 per 4.5 acres
III	11-13	335	159	1 per 2.1 acres
Total or average		1,621	411	1 per 3.9 acres

[1]Nest trees totaled 414, but three nests were in ponderosa pine trees in riparian vegetation.

The 414 nest trees counted in the census is a minimum figure. A check of three areas within 2 weeks after they were inventoried by the field crew indicated the crew missed about one nest tree in 20 (5 percent). This is a low error, however, with little impact on number of nests in the three crown density classes.

An average nest density for the entire watershed does not adequately describe the squirrel-tree relationships. Even within classes, different densities can be found on small areas depending on how close the area is to the upper or lower limit of the class. Class I had an area with a density of one nest per 20 acres, and Class III has an area with one nest per 0.5 acre. Nevertheless, if nest tree density is an indicator of quality, then the tree crown density classes —which are relatively related to tree size —characterize pine stands with poor, fair, and good squirrel nesting habitat, respectively.

Characteristics of Nest Trees

Variation within the three classes could not be examined in detail from aerial photographs. The next step was to analyze cover site data to describe squirrel habitat in more specific terms. If many different combinations of diameter and density of trees are available such as in watershed 8, a squirrel should select those that best meet its requirements. By examining a large number of nest sites, some condition or combination of habitat components may be described as representing optimum nest cover.

Although 414 nest trees were found within the watershed, not all of them could be completely described because of time constraints. The 302 nest sites selected represent a 73 percent sample of 414 nest trees within the watershed boundary.

Nest Tree Diameter

Nest tree diameter provides insight into the selection of an individual tree within a stand. When the data are grouped into 3-inch diameter classes, four classes (those from 11 to 22 inches d.b.h.) include 80 percent of the nest trees:

Diameter class	Nest trees	
Inches d.b.h.	*Number*	*Percent of total*
8-10	13	4.3
11-13	64	21.2
14-16	99	32.8
17-19	45	14.9
20-22	33	10.9
23-25	15	5.0
26-28	16	5.3
29-31	7	2.3
32-34	6	2.0
35≥	4	1.3
Total	302	100.0

The mean d.b.h. (17.4 inches) is in the lower limit of the 17- to 19-inch class interval. The model class of nest trees is the 14- to 16-inch d.b.h. with 33 percent of the trees.

No nest trees were smaller than 8 inches, and trees above 22 inches diameter (older mature trees) account for 16 percent of the total. The largest tree selected for a nest was 38 inches. If trees of all diameters are available in the watershed, those from 14 to 16 inches d.b.h. with an optimum of 15 inches are most likely to be selected for nest trees by squirrels.

The largest trees selected for nests were found on plots with the largest average tree diameters (table 2). Eighty-four percent of the nest inventory plots had trees whose diameters were larger than that of the nest tree. The tabulation below presents the frequency distribution of average d.b.h. of all trees on the plots:

Table 2.--Plots classified by density, with average diameter at breast height (d.b.h.) of the stand and of the nest trees

Stand density (trees/acre)	Plots	Average d.b.h. of--	
		Stand	Nest tree
	No.	- - - *Inches* - - -	
≤ 50	12	20.2	22.7
51-100	44	17.1	22.7
101-150	50	14.0	20.0
151-200	52	12.3	16.7
201-250	76	12.0	14.7
251-300	47	11.6	14.8
301-350	13	11.4	14.4
351≥	8	10.8	12.9
Total	302		

Diameter class	Nest inventory plots	
Inches d.b.h.	*Number*	*Percent of total*
8-10	17	5.6
11-13	195	64.6
14-16	50	16.6
17-19	21	6.9
20-22	13	4.3
23≥	6	2.0
Total	302	100.0

Of 302 plots, 195 (65 percent) had an average d.b.h. in the 11- to 13-inch class and 50 (16 percent) were in the 14- to 16-inch class. These two classes account for 81 percent of all inventory plots. This high percentage indicates squirrels have a strong tendency to select the smaller stands for cover, particularly those in the 11- to 13-inch d.b.h. range. Trees in this diameter class generally have a denser crown and would provide more protection from weather than large older trees.

Vigor and Position

Two vigor classes (B and C) account for 76 percent of the trees used for nests:

Vigor class	Nest trees	
	Number	*Percent of total*
AA	17	5.6
A	55	18.2
B	125	41.4
C	105	34.8
Total	302	100.0

A tree did not need a large crown volume to be selected for a nest tree; B and C classes have from 20 to 55 percent of the total tree height in crown.

Each nest tree was classified by its postion relative to other trees on the plot. Ninety-two percent of all nest trees were located in interior positions.

Position	Nest trees	
	Number	*Percent of total*
Isolated	0	0.0
Open	12	4.0
Marginal	12	4.0
Interior	278	92.0
Total	302	100.0

A nest tree located in a group of trees, with crowns interlocking or only a few feet apart, offers protection and many escape routes as opposed to a nest tree in a less dense stand.

An indication of tree grouping was obtained by recording the number of trees with crowns interlocking the crown of the nest tree. Results show 75 percent of the nest sites had three or more trees interlocking the crown of the nest tree. Trees interlocking to this extent would provide easy access to and from the nest. Some nest trees had as many as six interlocking trees, and every nest tree had at least one. Also there is an additive effect of crown volume when trees are clumped. A clump of young trees with interlocking branches forms a compact area—more so than older trees with less volume.

Age and Age Class

Annual rings indicate that 66 percent of the nest trees were between 51 and 100 years of age. Only 5 percent of the nest trees were over 200 years old. For management purposes, age of nest trees may be indirectly classified by qualitative characteristics associated with tree age. Age Class II (blackjack) accounted for 53 percent of the nest trees. Eighteen percent were in the youngest age class (Class I). Age Classes III and IV accounted for 29 percent of the nest trees.

Mistletoe Infection

The amount of mistletoe contained in the nest trees was small. Ninety-three percent of the trees had a zero rating. Only two trees had a rating of heavy mistletoe infection. Six percent of the trees recorded in the timber inventory

had some mistletoe in their crowns, which would indicate a light infection in the watershed.

Dominance Class

Tree dominance indicates the amount of light a crown receives at different levels in the forest canopy. Nearly three-fourths of the 302 nest trees were codominants, again indicating squirrels prefer a crowded tree within a group for cover:

Dominance class	Nest trees Number	Percent of total
Isolated	4	1.3
Dominant	65	21.5
Codominant	217	71.8
Intermediate	15	5.0
Overtopped	1	.4
Total	302	100.0

Nest Location

Abert squirrels seldom built more than one nest in the same tree. Only four trees were found with two nests; none had more. One large pine containing two nests was found in an open area surrounded by several large Gambel oak. Otherwise, the nest trees were not different from those normally selected.

Eighty percent of the nests were located on a limb next to the tree trunk (fig. 3). Only 5 percent were located in the fork of a tree, even though 80 percent of the inventory plots had forked trees. Those nests (15 percent) located further out on a limb were mostly in "witches' brooms" of ponderosa pine twigs.

Figure 3.—Nest location next to the tree trunk.

A second location factor is height of the nest in a tree. Comparing tree height to nest distance from the ground indicates a favored zone for nest location within the forest canopy from 30 to 50 feet above the ground (fig. 4). Seventy-six percent of the nests were located in this 20-foot-wide zone. Equal numbers (12 percent) were located below 30 and above 50 feet. The lowest nest was 18 feet above the ground in a tree 53 feet tall. A tree 90 feet tall had the highest nest (84 feet).

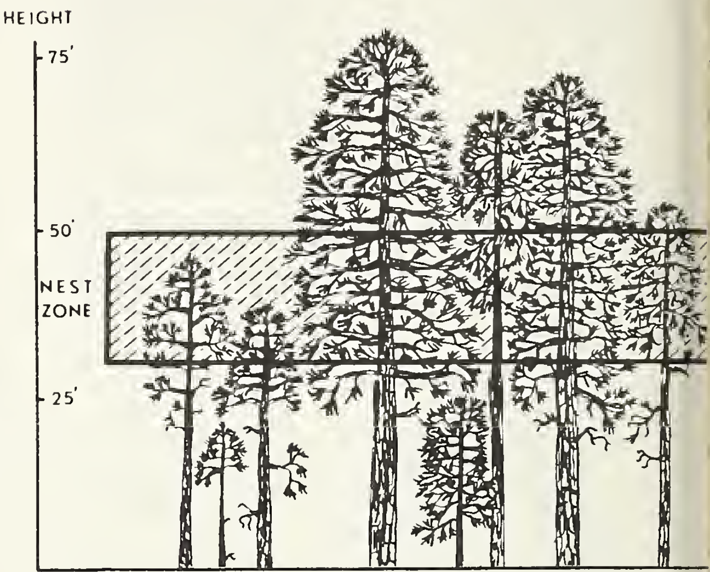

Figure 4.—Nest zone within the ponderosa pine canopy.

Nest Size and Construction

At each nest tree an estimate was made of the nest size in thickness and diameter. Ninety-one percent of the nests were between 10 and 18 inches diameter with an average of 14 inches. Most (90 percent) of the nests were between 6 and 12 inches thick with an average of 10 inches.

Construction material consisted of interwoven twigs and needles from ponderosa pine. In three cases, nests were built from oak leaves instead of ponderosa pine twigs. Material for lining the nest almost always includes dry grasses. Other materials used were plastic bags, horse hair, rabbit fur, and Spanish moss.

Characteristics of Trees Surrounding the Nest Tree

Experience gained while locating the nest trees suggested that the probability of finding a

nest was directly related to tree density and tree diameter. If squirrels purposely were selecting cover sites with high tree densities, tree density on areas they have selected should be higher than the watershed average.

Density

Nest tree inventory plots had greater density of trees than timber inventory plots for every tree diameter class but one (30 inches d.b.h., table 3). The greatest difference was in the 12-inch class.

Table 3.--Average number of trees per acre on timber inventory plots and nest tree inventory plots, by d.b.h. class

Size class (Inches d.b.h.)	Timber inventory	Nest-tree inventory	Difference
	- - - -	*Trees/acre*	- - - -
8	36.0	51.8	+15.8
10	29.9	47.4	+17.5
12	16.8	35.0	+18.2
14	10.1	23.4	+13.3
16	4.6	13.7	+ 9.1
18	3.9	6.8	+ 2.9
20	2.5	4.9	+ 2.4
22	1.6	3.0	+ 1.4
24	1.1	2.0	+ .9
26	1.1	1.3	+ .2
28	.7	1.0	+ .3
30	.7	.5	- .2
32	.1	.5	+ .4
Total	109.1	191.3	+82.2

Nest inventory plots were separated into eight classes based on the number of trees per acre. Stand densities from 51 to 300 trees per acre account for 89 percent of all nest sites:

Trees per acre *Number*	Nest trees *Number*	Nest trees *Percent of total*
≤50	12	4.0
51-100	44	14.6
101-150	50	16.6
151-200	52	17.2
201-250	76	25.2
251-300	47	15.5
301-350	13	4.3
351≥	8	2.6
Total	302	100.0

The distribution is moderately uniform in this density range.

Basal area is the most frequent measure used by foresters to express tree density (Husch 1963). When nest inventory plots are stratified by basal area, the frequency distribution shows three classes from 101 to 250 square feet per acre accounting for 84 percent of the nest sites. The highest percentage (36 percent) of plots was in the 151 to 200 square-foot-per-acre class:

Basal area per acre *(square feet)*	Nest inventory plots *Number*	Nest inventory plots *Percent of total*
≤50	0	0.0
51-100	18	6.0
101-150	69	22.8
151-200	108	35.8
201-250	77	25.5
251-300	22	7.3
301≥	8	2.6
Total	302	100.0

Canopy Coverage, Exposure, and Ground Cover

Data presented so far have indicated that most nest trees should be found in areas with a high crown density. Of 300 inventory plots, 88 percent had over 61 percent canopy coverage. Average canopy coverage increased from 58 percent with 75 trees per acre to 88 percent at 300 trees per acre. These figures are probably a little high (5 to 10 percent) due to a tendency to overestimate canopy coverage when using a spherical densiometer.

Some investigators (Keith 1965, Farentinos 1972) have suggested there is an association between exposure and nest location in a tree. Both the nest site and percent slope affect the amount of radiation received at the nest.

A chi-square test indicated no interaction, however, between nest exposure in a tree and exposure of the nest tree on a site. Thus, nest selection within a tree crown is probably independent of exposure and is not affected by slope of the site.

Woody and herbaceous understory vegetation is conspicuously absent from the nest sites. Litter comprised in excess of 81 percent of the ground cover on 96 percent of the plots, giving the forest floor a clean appearance. The lack of grasses, forbs, and shrubs is associated with the high tree density and canopy coverage, which inhibits herbaceous growth.

Tree densities that prevent herbaceous growth accumulate large amounts of tree litter. As this material decomposes it apparently

creates a favorable condition for certain fungi that are sought by squirrels for food throughout the year (fig. 5).

Figure 5.—An Abert squirrel has been digging in pine litter for fungi.

Slope and Position on Slope

Fifty-nine percent of the plots were on slopes of less than 10 percent. Fifteen percent were on slopes greater than 20 percent. The steepest slope with a nest tree was 45 percent. The middle slope position accounted for 42 percent of the nest sites. A middle position may be selected by squirrels because it is not subject to as much wind as the upper slopes (Buck 1964) and is less affected by nighttime cooling than lower slopes (Rosche 1958, Bergen 1969). The lower slopes had 23 percent of the nest trees; the upper had 35 percent.

Oak Associated with Cover Sites

Patton and Green (1970) have shown that hollow Gambel oaks are used by squirrels for nests (dens). In watershed 8, none of the leaf nests were in oak trees, even though 124 (41 percent) nest inventory plots had oak trees over 8 inches in diameter that presumably could be used as nest trees. One reason for not building nests in oak trees is because they are deciduous and the nest would be exposed in the winter.

During the nest inventory, no Gambel oak den trees were found. After the inventory was completed, however, squirrels instrumented with radio transmitters were tracked and found to be staying overnight in hollow oak. Thus, oaks may be used more than can be determined by inventory methods or relying on sight observations.

Oaks are probably more important to squirrels as a source of food than for nest trees. Acorns constitute as much as 40 percent of the fall diet when a good crop is available (Stephenson 1974). Trees in the 12- to 14-inch d.b.h. class are considered the best acorn producers (Reynolds et al. 1970). Timber inventory data from watershed 8 indicate 2.9 oaks per acre in the 12- to 14-inch d.b.h. class. The average diameter of 297 oaks over 8 inches d.b.h. on 124 sites selected by squirrels was 13.4 inches d.b.h. At present, there are no data available to compare the number of squirrel nest trees in ponderosa pine stands with and without oak.

Oak trees in watershed 8 were frequently used for den trees by red squirrels. On one occasion when a red squirrel had just placed a cone in a large hollow tree, an Abert came in behind him and removed the cone.

Cone Production at Cover Sites

Larson and Schubert (1970) have determined that cone production of single ponderosa pine trees is a function of tree size and vigor. The largest and most vigorous isolated trees are the best cone producers. A 40-inch tree produces over 20 times more cones than a 20-inch tree:

Diameter class	Cone production
Inches d.b.h.	*Number*
12-16	6
16-20	21
20-24	75
24-28	139
28-32	218
32-36	306
36-40	446

Although the best cone producers are the largest trees, they are not present in high numbers. Trees 20 inches d.b.h. and larger account for 7.8 trees per acre in watershed 8. In the nest tree inventory the same tree sizes amounted to 13.2 trees per acre (table 3).

Fifty-six percent of the sites selected for nests had one or more trees over 20 inches capable of producing cones. Although small trees do not produce many cones, when present at high tree densities, their combined production could be significant. A stand table prepared for sites most often selected for cover shows that 74 percent or 720 cones per acre are possible from trees 12 to 20 inches d.b.h. (table 4). In reality cone production would probably be less than indicated because most of the trees will have an interior position. The significant factor is that

nest sites had some trees either at or adjacent to the site that were capable of producing cones.

Table 4.--Cone production at sites most often selected for cover

Size class (Inches d.b.h.)	Cones per tree	Trees[1] per acre	Cones per acre	Cumulative percent
	- - -	*Number*	- - -	
12-16	6	99.0	594	61
16-20	21	6.0	126	74
20-24	75	2.3	173	92
24-28	139	.4	56	98
28-32	218	.1	22	100
Total		107.8	971	

[1]Trees between 8 and 12 inches d.b.h. account for 135 trees per acre, but they do not contribute to the cone crop.

Figure 6.—Good squirrel cover contains a large number of small groups of trees (crown density class III), but with some groups of larger trees in the stand.

CONCLUSIONS AND MANAGEMENT APPLICATIONS

The evidence in this study indicates tree density, diameter, and a grouped distribution of trees are the most important components of Abert squirrel nest cover. In the right combinations these factors provide squirrels with optimum conditions necessary for nest protection. Cover factors for nest site selection have well defined upper and lower limits. Data collected in the nest inventory can be brought together to describe the conditions most often selected by the Abert squirrel for cover in watershed 8 of the Beaver Creek Watershed, an area reasonably representative of both "pine country" and "squirrel country" in Arizona.

A Description of Abert Squirrel Cover Sites

The best cover conditions are found in uneven-aged ponderosa pine stands with trees spaced in small even-aged groups within the stand. These pine stands have densities between 201 and 250 trees per acre (fig. 6). Average tree diameter for the stand is between 11 and 13 inches d.b.h., but small groups of larger trees are present which produces a mosaic of height groups. Basal area of trees over 8 inches d.b.h. in the stand is between 151 and 200 square feet per acre. Gambel oak is found in the stand in densities of one to two trees per acre in the 12- to 14-inch d.b.h. class.

A typical nest tree within a stand is a codominant, interior pine with its crown making up 35 to 55 percent of the tree height. It is usually a blackjack pine between 50 to 100 years old with a diameter of 14 to 16 inches d.b.h., but may not be the largest tree in the stand. Several adjacent trees of similar size have their crowns touching or interlocking, thereby forming a group with several escape routes.

The nest itself is most often located on a limb against the tree trunk between 30 and 50 feet above the ground. It can face in any direction. The nest site has a canopy coverage greater than 80 percent on a slope of 10 percent or less. Optimum site characteristics include ground cover of at least 80 percent litter on a middle slope position.

Evaluating Squirrel Habitat

Wildlife biologists need to be able to determine the quality of squirrel habitat and how quality is changed by forest succession and forest management practices. Criteria describing cover in this study are being combined with food habits data from other studies to develop an Abert squirrel habitat model. This model will emphasize the ranking of habitat quality (poor, fair, etc.) as determined by different combinations of tree sizes and densities.

The criteria used in the model must be validated in different areas before they can be applied in general to all ponderosa pine forests. In

the meantime biologists can use the description of optimum cover as a standard for comparing squirrel habitat in other areas.

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Describes the characteristics of ponderosa pine trees and stands selected by the Abert squirrel for cover. Presents data on basal area, tree density and size, tree vigor, dominance and age class, nest location, and nest tree density in a pine forest. Discusses the data's relevance for evaluating the quality of Abert squirrel habitat.

Keywords: Abert squirrel, ponderosa pine, habitat evaluation, squirrel cover.

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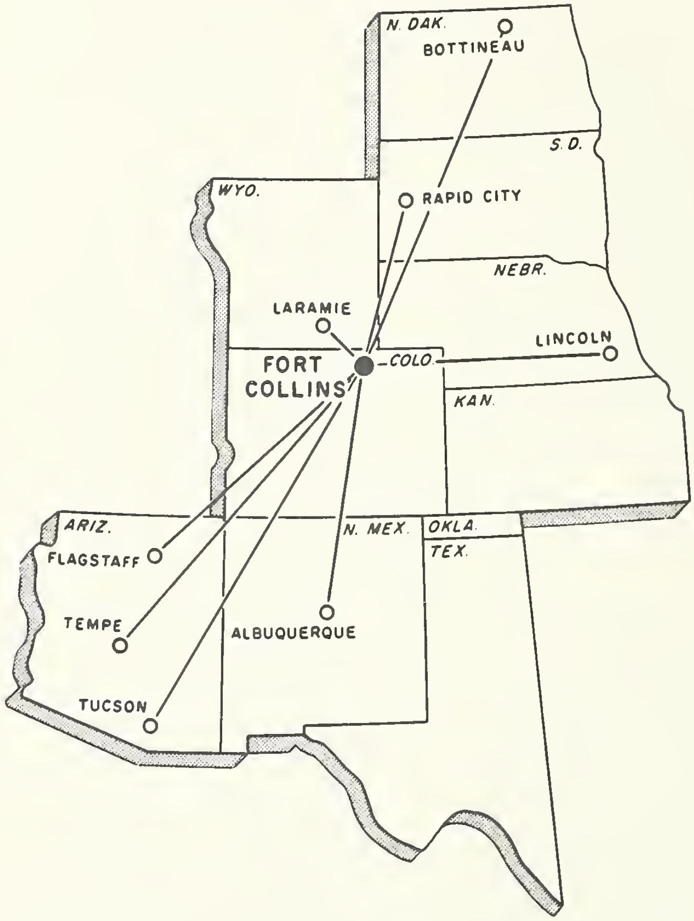
COMMON AND SCIENTIFIC NAMES OF PLANTS AND ANIMALS MENTIONED

Plants

Aspen	*Populus tremuloides*
Ceanothus, Fendler	*Ceanothus fendleri*
Clovers	*Trifolium* spp.
Fescue, Arizona	*Festuca arizonica*
Geraniums	*Geranium* spp.
Grama, blue	*Bouteloua gracilis*
Junegrass	*Koeleria cristata*
Locust, New-Mexican	*Robinia neomexicana*
Muhly, mountain	*Muhlenbergia montana*
Oak, Gambel	*Quercus gambelii*
Peavine	*Lathyrus* spp.
Pine, ponderosa	*Pinus ponderosa*

Animals

Bobcat	*Lynx rufus*
Coyote	*Canis latrans*
Deer, mule	*Odocoileus hemionus*
Dove, mourning	*Zenaidura macrocura*
Elk	*Cervus canadensis*
Goshawk	*Accipiter gentilis*
Hawk, red-tailed	*Buteo jamaicensis*
Junco, gray-headed	*Junco caniceps*
Nuthatch, pygmy	*Sitta pygmaea*
Rabbit, cottontail	*Sylvilagus nuttallii*
Raccoon	*Procyon lotor*
Squirrel, Abert	*Sciurus aberti aberti*
Squirrel, Kaibab	*Sciurus aberti kaibabensis*
Squirrel, red	*Tamiasciurus hudsonicus*
Swallow, violet-green	*Tachycineta thalassina*
Turkey, Merriam's	*Meleagris gallopavo merriami*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